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ABSTRACT

Simulation is defined and its use, as related to three types of models, iconic, analogue, and symbolic, that may be utilized in educational research is discussed. A five-step procedure is outlined that can be followed in the process of symbolic model construction. Simulation methods, based on these three models, are examined, and illustrations of each method are presented and discussed. The report points out the advantages of the simulation approach as being 1) the ability to control many features of a system that one would not usually control in practice and thus relate known manipulations to known results, 2) control of time and cost scales, and 3) the ability to carry out experimental testing of hypothetical conditions that do not yet exist. Limitations of the simulation approach are seen in terms of 1) indiscriminate use of large-scale system simulation which results in the construction of models that become goals rather than means to a goal, 2) the relatively high cost of digital simulation, and 3) the need for careful selection of input conditions and specific output required. (AE)

SIMULATION MODEL AND EDUCATIONAL RESEARCH*

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Simulation Model and Educational Research

Within the last few years simulation has achieved the position of a new discipline in engineering science. Recently this technique has been applied to different areas in education. Understanding this development is of special interest in transferring the techniques of analysis in other fields to that of education.

To simulate, according to dictionary definition, is to give the appearance or effect of; to have the characteristics of. Actually, for our present purposes simulation is better described by operating a model.

A model is a representation of the system under study, a representation which levels itself to use in predicting the effect on the system's effectiveness of possible changes in the system.

There are three types of models which could be used in educational research: an iconic model, an analogue model and a symbolic model. An iconic model pictorically or visually represents what the system looks like as does a photograph or a mock-up. An analogue model employs one set of properties to represent some other set of properties possessed by the system being studied. Graphs are very simple analogues. In graphs we use distance to represent such properties as time, number, percent, age, weight, and many other properties. A symbolic model is one which uses symbols to designate properties of the system under study by means of a mathematical equation or set of such equations. Of the three types of models to be considered -- the iconic, analogue, and symbolic -- the latter is of particular importance. By proper mathematical or logical operations, the symbolic model can be used to formulate a solution to the problem at hand.

We can begin to construct a symbolic model of the System by itemizing all the components of the system which contribute to the effectiveness or ineffectiveness of the operation of the system. Once a complete list of the components is composed, the next step is to determine whether or not each of those components should be taken into account. This could be done for each component listed by determining whether or not this component is affected by the choice of an action from among alternatives. Frequently one or more of the components are independent of the choice from among the alternative courses of action being considered in the study.

At this stage in the development of the model, it may not be clear whether or not the effect of a component is significant. It may be assumed that the effect can be disregarded and that this component can be temporarily dropped from consideration. But the assumption should be checked when the information and research tools for doing so are available.

In some cases the system is not understood well enough to provide assurance that the availables listed are pertinent. It may then be desirable either to test for pertinence experimentally or by statistical analysis of available data. That is, we may want to determine by experiment or analysis of available data whether or not the variables listed have anything to do with the effectiveness of the system. We may need to explore, make guesses and check them, and find out why the system operates as it does. Which factor produces the effects observed? What can be manipulated to produce the effects desired? The methods of designed experimentation are often useful in this type of exploratory investigation.

After the list of the factors were compiled by survey methods and designed experimentation, unimportant factors were eliminated, leaving a list of only a very few environmental factors which were pertinent. It may also be convenient to group certain components of the system.

For each component remaining on the modified list, it is necessary to determine whether its value is fixed or variable. If a component is variable, we should find those aspects of the system which affect its value. Once such a breakdown has been made for each variable component in the modified component list, it is convenient to assign a symbol to each subcomponent.

We may summarize the procedure of the model construction as follows: (1) itemizing all the components of the system, (2) determining the pertinence of components, (3) combining and dividing the components, (4) assigning a symbol to each subcomponent, (5) functioning the variables or components.

The purpose of constructing a model of a problem situation is to enable us to determine what values of the controllable variables (Xi) provide the best measure of performance (V) under conditions described by the parameters (Yi). Therefore once we have the model of the form

$$V = i(Xi.\ Yi)$$

we want to determine what values of Xi maximize V (if it is a measure of desirable performance). The solution of a problem, then, consists of a set of equations, one for each controllable variable, in the form

$$Xi = i\ (Yi)$$

where the values of Xi thus specified maximize or minimize V.

However, it should be kept in mind that we are concerned with deriving solutions from models. The value of the solution depends on how adequately the model represents the problem situation; the adequacy of the solution depends on the adequacy of the model.

Simulation is a way of using a model. A model represents a phenomenon, but the simulation initiates it. The models are photographs and these simulations are motion pictures.

Simulation procedures can be classified into three main types, depending on the kinds of models which are used: iconic, analogue, and symbolic.

Iconic Simulation: Iconic simulation is the manipulation of an iconic model under real or iconically represented conditions.

The map game is an example of iconic simulation which is played by teams of military officers, usinga map and movable pieces representing opposing troops. This chess-like exercise has been used for training in strategy, for testing proposed tactics, and for appraising topological and logistics constraints imposed by the terrain. Similarly, much can be learned from manipulating scale models of transportation systems, factory layouts, paperwork systems, and sample product lessons.

Analogue Simulation: This type of simulation involved the manipulation of an analogue model.

Example: A physical system which had the same mathematical properties as the system to be evaluated was constructed in order to investigate more easily the electrical analogs of mechanical properties. By combining analoguous components we can construct many analogous systems. For example, we can use electrical amplifier as an analog for mechanical gear trains that multiply angular rotation.

Analog simulation also allows simultaneous measurement of system values in many points of the system. In the PERT analog simulation one could evaluate the various activities of time and cost during the process of simulation.

Symbolic Simulation: Symbolic simulation is a process by which equations or symbols are evaluated. Random sampling from the probability density function lies at the heart of symbolic simulation. This application of sampling is called the Monte Carlo procedure. Symbolic simulations are best handled by a digital computer. The digital computer works with symbols, and the logical refinements of symbolic simulation are substantially greater than those of earlier forms of simulation. Every system relationship and interrelationship must be precisely spelled out. Special techniques have been developed to simulate physical experience. Because the digital computer works sequentially, making one computation or one decision at a time, extensive control routines are required. However, these disadvantages cannot often withstand the overwhelming advantages of flexibility, speed, and precision offered by digit equipment.

The advantage of simulation can be summarized. The researcher controls many features of the system that he would not usually control in practice and can therefore relate known manipulations to known results. In addition, he can control the time and cost scales. Many respected incidents that would take many years to experience in reality can be simulated in minutes or seconds. The cost of obtaining such simulated experience is usually much less, and frequently much safer, than experimentation with the real objects. Simulation permits the experimental testing of hypothetical conditions that do not exist as yet.

On the other hand, simulation also has its constraints. Because of the potential of large-scale simulation research using the digital computer, many researchers have fallen into severe pitfalls by indiscriminate use of this approach. Simulation is a means to a goal, not a goal itself. The purpose of constructing a simulation research is to solve a specific problem, to investigate the characteristics of the system, and to evaluate given alternatives. To embark upon a large-scale system simulation without clear objectives or goals in mind is to invite disaster.

There may be many easier ways to solve problems, to investigate the characteristics of the system, or to evaluate given alternatives. The technique of simulation should not be used if there is an easier method capable of being employed.

Generally, the digital simulation of a xomplex system is expensive. Although such a simulation may repay its own cost many times over, it is expensive to design, develop, and maintain. If the economic usefulness of the results is not kept in mind and if the technical aspect of simulation